An operational hydrological ensemble prediction system for the city of Zurich (Switzerland): assessing the added value of probabilistic forecasts

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1. Discharge monitoring and flood mitigation in the Sihl catchment

Figure 1: The Sihl River flows through Zurich center, beneath the central railway station.

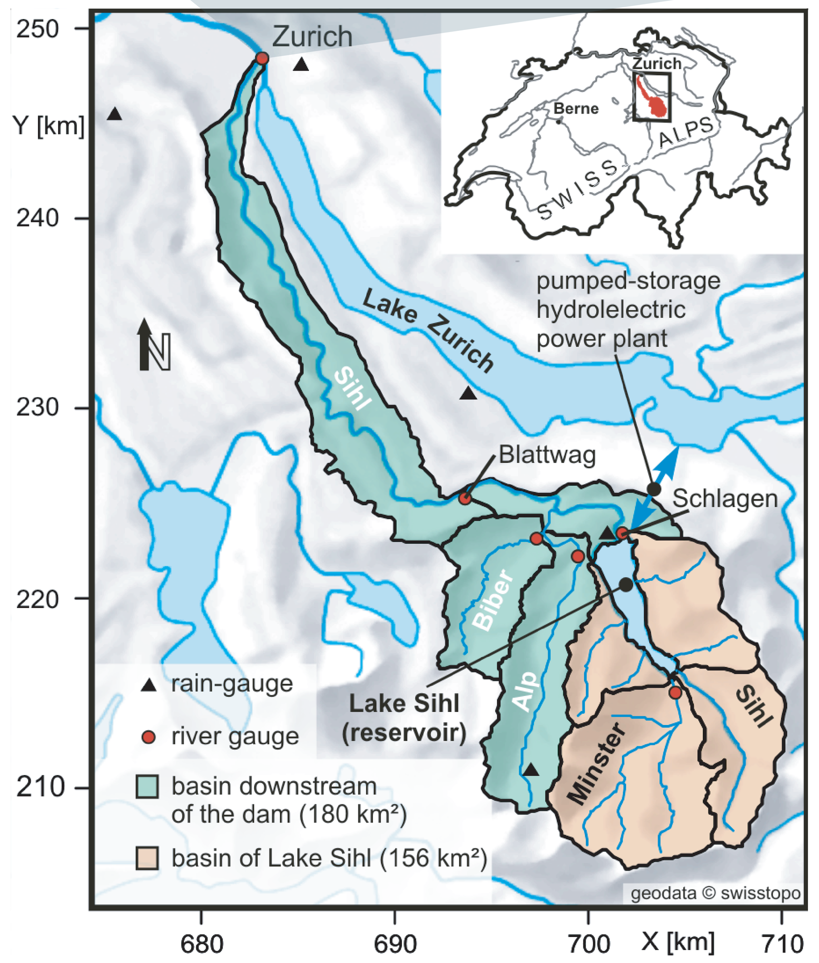

Figure 2: Map of the Sihl catchment. Note the Lake Sihl reservoir that can be used for flood buffering.

- The Sihl river represents the **largest flood threat** for the city of Zurich. This risk was enhanced during the construction (2008-2011) of an underground railway station below the river bed (Fig. 1).
- A panel of experts was created to anticipate and mitigate extreme discharge events. As a first flood **mitigation measure**, it can make decisions on preventive controlled water releases from the Lake Sihl reservoir, which enables flood buffering (Fig. 2).
- To provide **decision support**, an operational hydrometeorological ensemble prediction system (HEPS) was launched in 2008 (Fig. 3).

2. Evaluation of the operational hydrological ensemble prediction system

- In this study we investigate the HEPS suitability for the small-scale Sihl basin (336 km^2) and evaluate its potential for decision support using a 31-month (June 2007 to December 2009) **reforecast**.

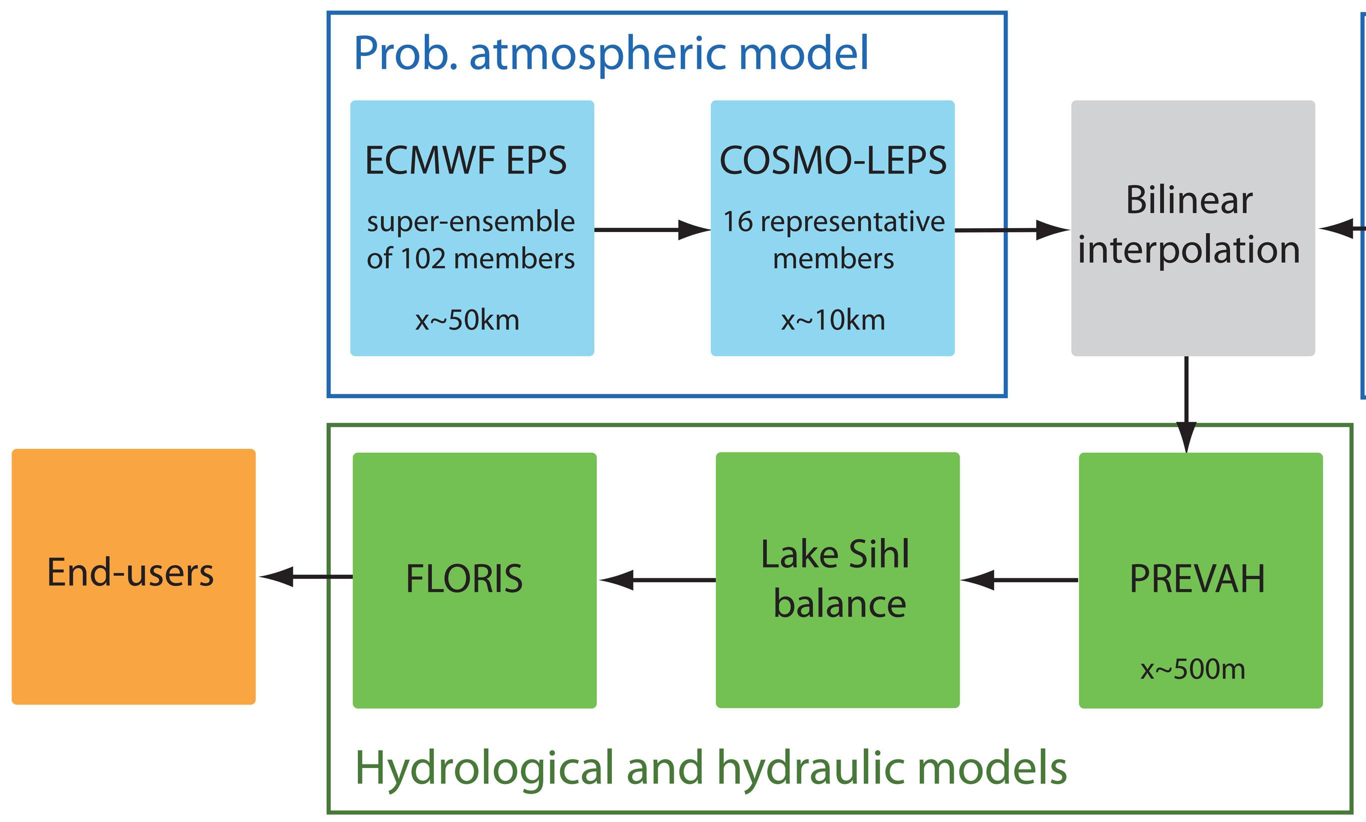

Figure 3: Flowchart of the prediction chain: probabilistic (COSMO-LEPS) and deterministic (COSMO-7) atmospheric forecasts are used to force the hydrological (PREVAH) and hydraulic (FLORIS) models.

5. Conclusions and outlook

- Although probabilistic forecasts do convey added-value in comparison to deterministic ones, precipitation forecasts must be improved to guarantee sufficiently early flood predictions in the Sihl catchment.
- Correct streamflow forecasts may not be sufficient for efficient flood mitigation if they are not accompanied by a dedicated tool to compare multiple mitigation actions.
- Rank histograms (not shown) reveal pronounced overconfidence in the probabilistic hydrological forecasts. Integrating more sources of uncertainty is required.
- No definitive conclusion on the model chain capacity to forecast flooding events endangering the city of Zurich could be drawn because of the under-sampling of extreme events.

3. Comparison of deterministic and probabilistic forecasts

- **Quantitative evidence of the benefits of the probabilistic approach:** Brier skill scores (BSS) for COSMO-LEPS-based forecasts are higher than those achieved using COSMO-7. This is valid for all lead times and thresholds.
- **Under-sampling of rare events:** the size of the error bars emphasizes that the uncertainty in evaluating model performance increases significantly with event intensity.

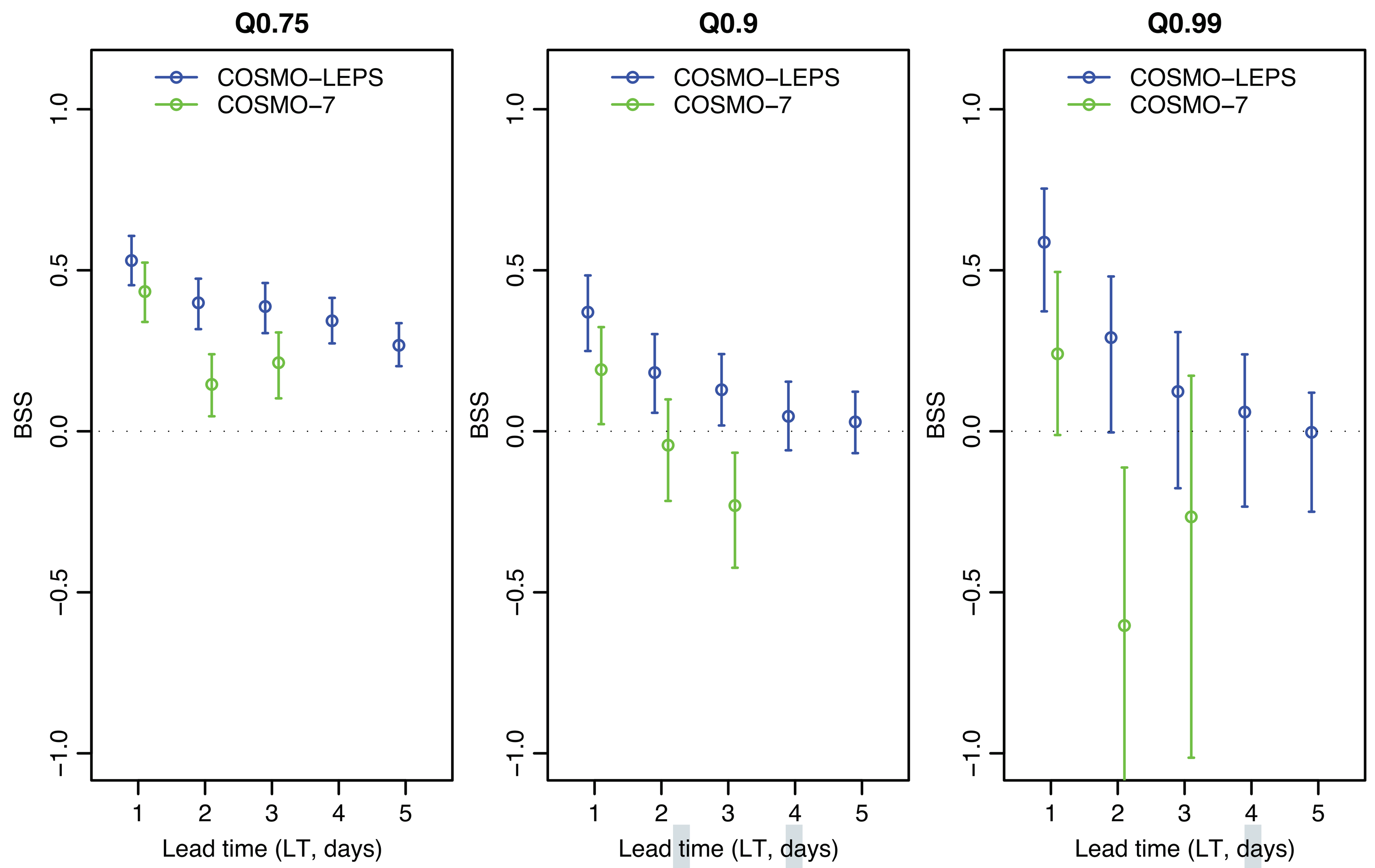

Figure 4: Brier skill scores (BSS, 1 perfect, 0 climatological forecast) for COSMO-LEPS- and COSMO-7-based forecasts for the daily maximum Sihl discharge in Zurich. Scores for the 75, 90 and 99% discharge quantiles (Q0.75, Q0.9 and Q0.99) are shown from left to right. The circles show the raw BSS, while the extremities of the confidence intervals give the 5th and 95th percentiles derived by bootstrapping.

- **Possible greater robustness of mid-term probabilistic forecasts:** due to the sampling of the initial atmospheric uncertainties, the decrease in performance with lead time seems to be faster for COSMO-7 than for COSMO-LEPS-based forecasts, in particular for the Q0.9 threshold.
- **Limited predictability of high discharge events:** in the small Sihl catchment, the mid-term forecasts (LT3 to LT5) for the Q0.9 and Q0.99 thresholds have little skill, and sometimes no skill.

- **Reference:** Addor, N., Jaun, S., Fundel, F., and Zappa, M.: An operational hydrological ensemble prediction system for the city of Zurich (Switzerland): skill, case studies and scenarios, *Hydrol. Earth Syst. Sci.*, 15, 2327-2347, doi:10.5194/hess-15-2327-2011, 2011.

4. Case study and scenario for the 15 August 2008 event

- We analyzed the most severe events of the period using a novel graphical representation: **'continuous persistence plots'** (Fig. 5 a).
- COSMO-LEPS- (resp. COSMO-7-) based forecasts improved (resp. worsened) with decreasing lead times (Fig. 5). Good performance of the hydrological/hydraulic part (HREF).

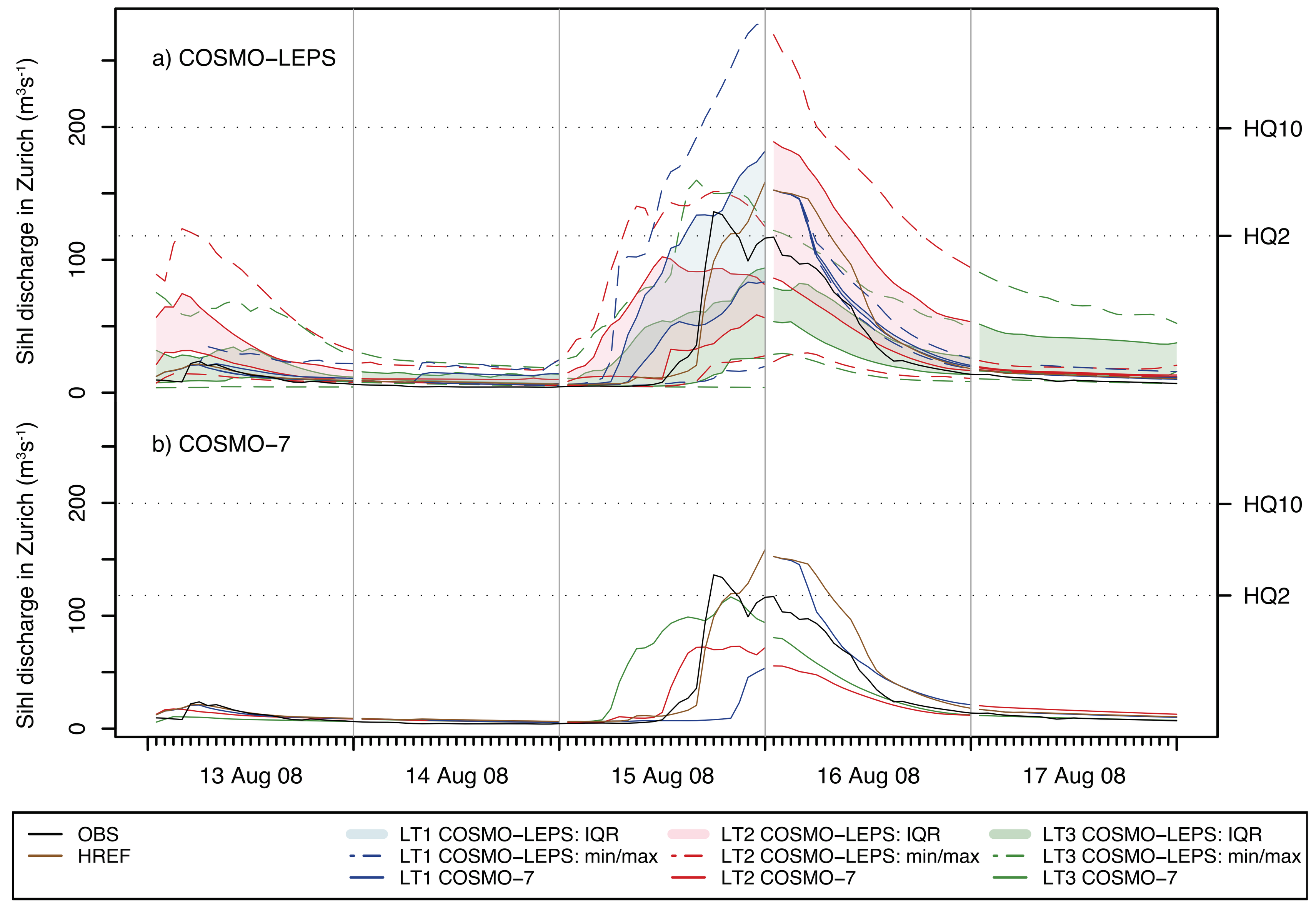

Figure 5: 'Continuous persistence plots' centred on the 15 August 2008 event depicting the discharge in Zurich. COSMO-LEPS- (a) and COSMO-7-based forecasts (b) are shown for lead times of 1, 2 and 3 days (LT1, LT2, LT3).

- A **scenario** with an artificially increased Sihl Lake level (889 m a.s.l. on 15 August 2008 at 00:00 UTC) was run to induce **dam overflow** (Fig. 6).
- The **risk of flooding of the railway construction site** (i.e. exceeding 300 m^{3}sec^{-1}) would have been correctly captured by the ensemble.

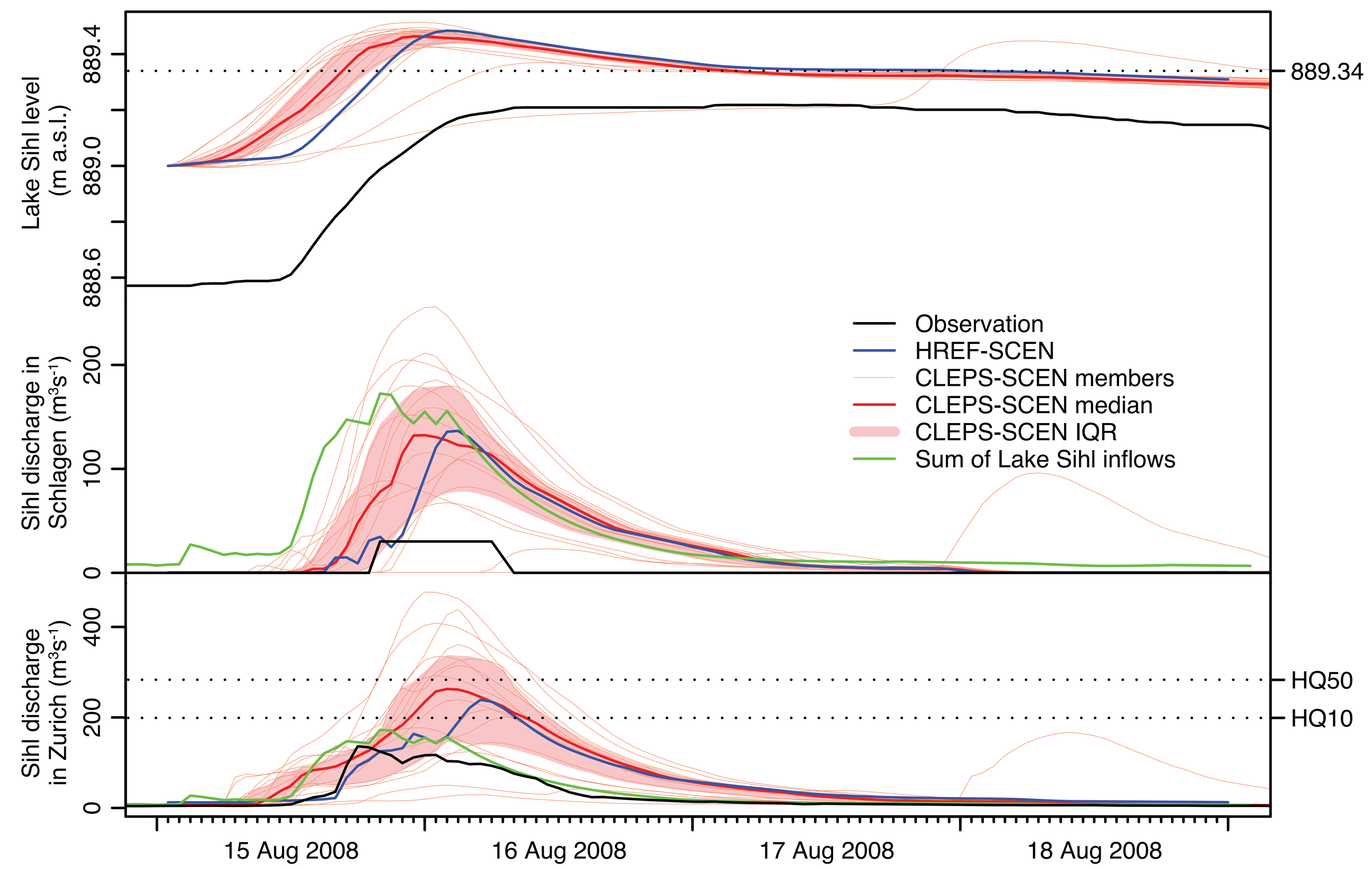

Figure 6: Scenario simulation of the Lake Sihl level (top), water released at the dam outlet (centre) and discharge in Zurich (bottom). The dotted horizontal line in the top plot indicates the altitude of the dam operation limit.

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